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Vietnam's processing and manufacturing industry – Energy efficiency and total factor productivity

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Abstract
This paper examines the impact of energy efficiency on firm-level productivity in Vietnam's processing and manufacturing sector over the period 2011–2022. Energy efficiency is proxied by energy intensity, while total factor productivity (TFP) is estimated using the Levinsohn–Petrin approach to address input simultaneity. A dynamic panel model is then estimated using two-step GMM to correct for endogeneity and productivity persistence. The results show a robust negative relationship between energy intensity and TFP, indicating that more energy-efficient firms are more productive. Capital deepening and firm age positively affect productivity, whereas inflation has a negative impact. Substantial heterogeneity across regions and industries reflects differences in technology, energy use, and industrial organization. The findings highlight the role of energy efficiency and macroeconomic stability in enhancing productivity in emerging economies.

Keywords: energy efficiency, processing and manufacturing industry, the generalized method of moments (GMM), total factor productivity (TFP)
JEL Classification Codes: D24, O47, L60, Q43

1. Introduction

Energy efficiency has emerged as a central pillar of public policy in developed economies, as it offers environmental, economic, and social benefits. Defined by the U.S. Department of Energy as the optimization of energy use to achieve equivalent outcomes, energy efficiency

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enhances industrial competitiveness, reduces emissions, lowers costs, and fosters job creation (Chan, 2007; Celani de Macedo, 2020). This study conceptualizes energy efficiency as a productivity-enhancing input: by curbing energy waste, reducing operating costs, and facilitating technological upgrading, it improves resource utilization and production flexibility, thereby raising total factor productivity (TFP). This perspective aligns with the Porter Hypothesis (Porter, 1991; Van der Linde, 1995), which posits that well-designed environmental regulations can spur innovation and competitiveness. While Vietnam has implemented policies such as the National Energy Efficiency Program (VNEEP), the absence of firm-level information on regulatory exposure in the Enterprise Survey precludes causal identification of policy effects. Accordingly, this study relies on firm-level variation in energy intensity, measured as the inverse of energy efficiency, as a proxy consistent with the Porter framework.

Empirical literature largely supports a positive relationship between energy efficiency and firm productivity, often using energy intensity as a proxy (Cantore et al., 2016; Montalbano et al., 2019; Zhang, 2020; Caragliu, 2021; Santos, 2021; Macharia, 2022). Alternative approaches include conservation supply curves (Worrell, 2003), comparisons between optimal and actual energy use (Hu, 2016; Jiang, 2021), and input–output models (Celani de Macedo, 2020). However, evidence is not uniform. Pons (2013) reports environmental gains without corresponding economic improvements, while Jiang (2021) finds a negative efficiency–productivity relationship in China's chemical sector, which suggests sectoral heterogeneity. Huang et al. (2025) further show that the decline in China's energy intensity is driven primarily by efficiency improvements rather than changes in economic structure. In developing economies such as Vietnam, where growth often relies on rising energy consumption rather than efficiency improvements (Cantore, 2016), firm-level evidence remains limited. Vietnam's processing and manufacturing sector accounted for 14.9% of GDP during 2011–2020 and consumed 47.5% of national energy in 2019. Using firm-level panel data from 2011–2022, this study employs a dynamic panel model estimated by the generalized method of moments (GMM) to examine the energy efficiency–TFP relationship; this approach addresses endogeneity and unobserved firm heterogeneity while capturing industry- and region-specific variation.

2. Methodology

2.1. Model specification

A firm i in industry j produces an output according to a Cobb–Douglas production function of the following form:

$$Y_{it}^{j} = A_{it}^{j} K_{it}^{j,\beta_k} L_{it}^{j,\beta_l} M_{it}^{j,\beta_m} \tag{1}$$

Here, Y_{it}^{j}, K_{it}^{j}, L_{it}^{j}, and M_{it}^{j} represent the output, labour input, capital, and raw material (intermediate input) respectively. A is a constant, while the coefficients for labour, capital, and raw materials are β_l, β_k, and β_m respectively. The indices *i*, *j*, and *t* denote firm *i*, industry *j*, and year *t*, respectively.

After applying the logarithmic transformation to both sides of Equation (1) and splitting the error term into two components, ω_{it} and ε_{it}^{j} (Levinsohn & Petrin, 2003), the following form of equation (1) can be obtained:

$$y_{it}^{j} = \alpha + \beta_l l_{it}^{j} + \beta_m m_{it}^{j} + \beta_k k_{it}^{j} + \omega_{it} + \varepsilon_{it}^{j} \quad (2)$$

The productivity component ω_{it} represents an unobserved error term, while ε_{it}^{j} is an independently and identically distributed (i.i.d.) term that does not influence the firm's decisions. It represents unpredictable shocks with a mean of zero for realized productivity after inputs are selected.

Model (2) may face endogeneity due to TFP's simultaneous impact on output and inputs, with unobserved factors causing bias. Levinsohn and Petrin (2003) refined Olley and Pakes' method, using investment as a proxy for productivity shocks, assuming it is non-negative and essential.

Thus, based on Model (2), TFP can be calculated as follows:

$$TFP_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} - \hat{\beta}_k k_{it} \quad (3)$$

The results of estimating the TFP model using enterprise survey data from 2011 to 2021 are as follows:

According to Cantore (2016), Montalbano (2019), and Macharia (2022), TFP is modelled as a function of the energy efficiency index:

$$TFP_{it} = f(EI_{it}) \quad (4)$$

In this model, EI_{it}represents the energy intensity index of firm i in year t. Prior research identifies multiple determinants of TFP. At the firm level, these include research and development investment (Romer, 1986), capital intensity (Rath, 2018), firm age (Arrow, 1962; Fernandes, 2008), foreign ownership (Harris, 2003), and firm size (Şeker & Correa, 2018). Macroeconomic conditions also play an important role, particularly trade openness (Girma, 2004) and inflation-related macroeconomic instability (Cevik & Teksoz, 2024). In addition, the literature highlights the influence of industry concentration, managerial quality, workforce skills, financial constraints, and capital structure. Drawing on these insights, the empirical model combines Equations (3) and (4) to estimate the impact of energy intensity on firm-level TFP:

$$lnTFP_{it} = \beta_0 + \beta_{EE} lnEI_{it} + \beta_C C_{it} + \beta_W W_i + \mu_{it} \quad (5)$$

The prefix ln represents the logarithmic form of the variables.

- C_{it} refers to time-varying factors, meaning these are variables that can change over time for a given firm. Examples include capital intensity, firm age, size, the Herfindahl–Hirschman Index (HHI), import/export activity, and inflation.
- W_i refers to time-invariant factors, which are characteristics of firms that do not change over time. These include the firm's location, industry sector, and initial technology level.

In Model (5), β_0 and μ_{it} denote the intercept and error term, while β_{EE}, β_C, and β_W are the coefficients for energy efficiency, time-varying, and time-invariant factors, respectively. Endogeneity from omitted variables (e.g., managerial capability), and reverse causality where energy efficiency boosts TFP and vice versa, may bias estimates (Cantore et al., 2016; Macharia, 2022). To address this, lagged TFP is included, yielding a dynamic panel specification of Model (5):

$$lnTFP_{it} = \beta_0 + \beta_P lnTFP_{it-1} + \beta_{EE} lnEI_{it} + \beta_C C_{it} + \beta_W W_i + \mu_{it} \quad (6)$$

Here, TFP_{it-1} represents the TFP of firm i lagged by one period. The coefficient β_P captures the persistence of TFP, reflecting how TFP in the previous period affects TFP in the current period. Macharia (2022) explains that a lagged model reduces the response effect from TFP to EI; this implies that decisions to improve energy efficiency technologies made in earlier stages are based on the firm's operational efficiency.

2.2. Calculation of variables in the model

a) Calculation of TFP: TFP is estimated using Stata via the Levinsohn and Petrin (2003) semi-parametric method, which addresses simultaneity bias by using intermediate inputs as proxies for unobserved productivity shocks, thus improving upon Olley and Pakes (1996). Estimation follows the Rovigatti and Mollisi (2018) algorithm, to ensure consistency. The resulting firm-level TFP estimates (from Eq. 3) serve as the dependent variable in subsequent regressions. Energy intensity (energy use per unit of value added) is adopted as the energy efficiency proxy, consistent with firm-level literature (e.g., Cantore et al., 2016). Although limited in capturing technological improvements, alternatives (e.g., cost shares, physical efficiency scores) are infeasible due to data constraints in the Vietnamese enterprise survey.

b) Calculation of energy intensity: energy intensity has been widely recognized as a suitable metric for evaluating energy efficiency, due to its simplicity and practical application in policy development and assessment (Fan, 2017). Several studies, including those by Subrahmanya (2006), Cantore (2016), Montalbano (2019), and Macharia (2022), have employed the energy intensity index to assess energy efficiency.

In line with this approach, this study computes energy utilization efficiency using the following formula:

$$EI_{it} = \frac{E_{it}}{VA_{it}} \tag{7}$$

Here, E_{it} represents the energy consumption of enterprise *i* in year *t*, and VA_{it} denotes the value added by enterprise *i* in year *t*.

c) Other variables in the model: capital is measured as fixed assets and is captured via capital intensity (the capital–labour ratio), to reflect technological level and productivity (Rath, 2018). Control variables include firm age, size, foreign ownership (D_FDI), export status, R&D, and managerial experience (Fernandes, 2008; Kreuser & Newman, 2018; Şeker, 2018; Macharia, 2022). Older firms may benefit from learning-by-doing but they risk technological obsolescence (Harris & Moffat, 2015); however, experienced managers enhance efficiency (Fernandes, 2008). FDI firms often transfer advanced technologies (Harris & Robinson, 2002; Zhou, 2002). Larger firms may enjoy scale economies (Satpathy, 2017), while smaller ones gain from agility (Şeker, 2018). Market concentration is measured by the HHI; that is, the sum of squared revenue-based market shares within each industry–year cell (Liston-Heyes, 2004). Formally, for industry j in year t:

$$HHI_{jt} = \sum_{i \in j} s_{ijt}^2, \tag{8}$$

Where s_{ijt} is firm i's revenue share in sector j and year t. The index ranges from 0 to 1, with higher values indicating more concentrated markets. Export status is also captured via a dummy, with exporters showing higher productivity due to technological upgrading and foreign market competition (Aw & Hwang, 1995; Bernard, 1995; Tybout, 1998; Wagner, 2005; Fernandes, 2008).

Finally, inflation proxied by the output level inflation rate can influence firm productivity through input price volatility and macroeconomic uncertainty (Cevik, 2024).

2.3. Estimation method

Model (6) may exhibit heteroscedasticity and endogeneity due to firm-specific factors and reverse causality, particularly with lagged TFP. Fixed or random effects estimators cannot address simultaneity bias. We therefore employ GMM estimators (Hansen, 1982; Arellano & Bond, 1991), which use lagged variables as internal instruments to correct for endogeneity and heteroscedasticity. Following Roodman (2009), we limit instrument depth and apply the collapse option to avoid proliferation. Model validity is confirmed by Hansen J-tests and AR(1)/AR(2) tests reported in all regressions.

3. Data

This study uses a unified unbalanced panel dataset (2011–2022) constructed from the Vietnam Enterprise Survey (National Statistics Office), supplemented with provincial-level PCI and GDP data from Provincial Statistical Yearbooks. Data cleaning involved removing observations with missing enterprise type, industry code, or zero/missing values for key variables such as employment and fixed assets. Energy consumption was defined as total monetary expenditure on electricity, fuel, gas, and other energy inputs, consistently reported across all survey years. Energy intensity (EI) was calculated as energy expenditure divided by firm-level value added; extreme EI values (below 0.01 or above 10) were excluded, and the sample was further trimmed using 1st–99th percentile thresholds to mitigate outliers. Firms were classified according to Enterprise Law No. 59/2020/QH14 and grouped by the Vietnam Standard Industrial Classification (VSIC 2018), aggregated into processing and manufacturing sectors (see Appendix 2). Enterprise size followed Decree 80/2021/NĐ-CP, based on average annual insured employees, with thresholds varying by sector; large firms exceeded medium-size limits. Firm age was recalculated for consistency. Due to the absence of physical energy data, all energy variables were measured in monetary terms (see Appendix 3).

Table 1. Description of the variables

Variable	Symbol	Calculation method	Data collection source
Total Factor Productivity	TFP	Calculated from the semi-parametric model	From the Enterprise Survey, NSO
Energy intensity	EI	The ratio of energy consumption to value added	From the Enterprise Survey, NSO
Labor	l	Average employment = (Employment at the beginning of the year +Employment at the end of the year)/2	From the Enterprise Survey, NSO
Capital	k	Fixed assets	From the Enterprise Survey, NSO
Intermediate input	m	Includes spending on raw materials, fuel, electricity, outsourced services, spare parts, and other production-related inputs, but it excludes depreciation of fixed assets, labour costs, financial expenses, and investment.	From the Enterprise Survey, NSO
Capital/labour ratio	LR	Capital/labour	From the Enterprise Survey, NSO
Firm age	Firmage	Number of years in production and business operation	From the Enterprise Survey, NSO
Firm size	Firmsize	Based on Decree 80/2021/NĐ-CP	From the Enterprise Survey, NSO
FDI firm dummy variable	D_FDI	Equals 1 if the firm is classified as FDI and 0 otherwise	From the Enterprise Survey, NSO
Industrial concentration level	HHI	Two-digit industry-level HHI based on the VSIC 2018 classification	From Enterprise Survey, NSO

Firms participating in imports and export	XK	Equal to 1 for firms participating in export/import activities and otherwise equal to 0	From the Enterprise Survey, NSO
Inflation Index	CPI	Logarithmic form of gross domestic product at current prices/gross domestic product at constant prices	NSO

4. Results

TFP was estimated using the Levinsohn–Petrin (2003) method, with intermediate consumption as the proxy for unobserved productivity shocks, as it is consistently reported and satisfies the monotonicity assumption. Alternative approaches such as ACF or Wooldridge (2009) were infeasible due to unreliable investment or materials data in Vietnam. The resulting firm-level TFP estimates were used in Model (6), which included a lagged dependent variable to capture productivity persistence. Region 4 (Central Highlands) was excluded owing to missing data and its agrarian economic structure. The model was estimated via two-step system GMM with robust standard errors. Instrument validity was confirmed by the Arellano–Bond test, which showed significant AR(1) but no AR(2) across all specifications, as required by GMM.

4.1. Estimated TFP overall and by region

Table 2 presents the TFP estimation results for the full sample and regions. The lagged TFP term is positive and significant across all models, indicating that current productivity is influenced by past performance. This persistence underscores the importance of sustained improvements in firm-level productivity over time.

Energy intensity is consistently and negatively associated with TFP across all regions, as well as in the national sample; this indicates that firms using less energy per unit of output tend to achieve higher productivity. This finding is consistent with Worrell (2003) and supports the view that energy efficiency enhances firm performance through improved resource utilization. Capital intensity exerts a strong and positive effect on TFP, thus reflecting productivity gains arising from investment in modern machinery and production technologies. Firm age and foreign direct investment are also positively related to productivity, in line with Fernandes (2008) and Jensen et al. (2001), which suggests the importance of learning effects and access to advanced knowledge and managerial practices. Firm size shows a statistically significant impact in several regions, although the magnitude varies across locations. Higher industry concentration, measured by the HHI, is associated with lower productivity, indicating that reduced competitive pressure may hinder efficiency improvements. Export participation is positively linked to TFP, particularly in Region 1, which highlights the role of international market exposure. Inflation exhibits a negative relationship with productivity. Regional disparities reflect differences in industrial structure and institutional quality: Region 2 faces outdated technology and weaker institutions, whereas Region 5 benefits from superior infrastructure, stronger industrial clustering, and more effective governance.

4.2. Estimation of TFP by several combined industry groups

The estimation results by firms' industry group confirm the dynamic nature of productivity, with lagged TFP having a consistently positive and significant effect across most sectors. EI remains negatively associated with TFP in nearly all industry groups, which reinforces the importance of energy efficiency regardless of sectoral context. Capital intensity and firm age generally show positive effects, while the impact of variables such as foreign ownership, firm size, market concentration, and inflation varies across groups, reflecting sector-specific structures (Table 3).

Table 2. Estimation results overall and by regions

VARIABLES	(1) Total	(2) Region 1	(3) Region 2	(4) Region 3	(5) Region 5	(6) Region 6
Lag of TFP	0.1506***	0.1605***	0.0738*	0.1564***	0.1257***	0.2169***
	(0.0124)	(0.0229)	(0.0404)	(0.0369)	(0.0182)	(0.0359)
EI	-0.2527***	-0.2329 ***	-0.2208 ***	-0.2362 ***	-0.3234 ***	-0.2169 ***
	(0.0127)	(0.0219)	(0.0360)	(0.0274)	(0.0274)	(0.0265)
Capital/labour ratio	0.0689***	0.0766***	0.0793**	0.0943***	0.0446***	0.1084***
	(0.0077)	(0.0139)	(0.0335)	(0.0220)	(0.0118)	(0.0296)
Firmage	0.0458***	0.0480***	0.0455***	0.0537***	0.0411***	0.0241**
	(0.0031)	(0.0055)	(0.0120)	(0.0090)	(0.0055)	(0.0100)
D_FDI	0.0647**	0.1052*	0.2195**	0.0332	0.0146	-0.0464
	(0.0322)	(0.0592)	(0.1101)	(0.0716)	(0.0618)	(0.0893)
Firmsize	-0.1189***	-0.0976 ***	-0.1350 ***	-0.1812 ***	-0.0979 ***	-0.1853 ***
	(0.0128)	(0.0231)	(0.0493)	(0.0381)	(0.0182)	(0.0501)
HHI	-13.0747 ***	-15.1784 **	-12.6085	-13.0588	-12.6352	5.0972**
	(4.8636)	(7.1622)	(20.2767)	(11.2473)	(12.3043)	(2.3874)
Firms participating in imports and export	0.0303**	0.0407*	-0.0003	0.0194	0.0268	0.0496
	(0.0129)	(0.0226)	(0.0670)	(0.0398)	(0.0185)	(0.0513)
Inflation	-0.6963***	-0.6175 ***	-0.7571 ***	-0.8886 ***	-0.3337**	-0.7487 ***
	(0.0535)	(0.0842)	(0.1290)	(0.1124)	(0.1549)	(0.1982)
Constant	2.1306***	1.9299***	2.2478***	1.9584***	2.3785***	2.0267***

		(0.0699)	(0.1181)	(0.2515)	(0.1883)	(0.1281)	(0.2356)
Observations		40,218	13,216	2,783	5,094	14,861	3,943
Number of ID		16,984	5,618	1,205	2,213	6,035	1,768
Arellano-Bond	AR1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
test0	AR2	0.0761	0.0631	0.7304	0.5993	0.3346	0.9729

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 3. Estimation results by industry groups

VARIABLE	**(1) Group 1**	**(2) Group 2**	**(3) Group 3**	**(4) Group 4**	**(5) Group 5**	**(6) Group 6**	**(7) Group 7**
Lag of TFP	0.1122***	0.1575***	0.1331***	0.1021***	0.1094***	0.1718**	0.1616 ***
	(0.0333)	(0.0272)	(0.0326)	(0.0344)	(0.0259)	(0.0796)	(0.0271)
EI	-0.2565***	-0.2726 ***	-0.2391***	-0.2834 ***	-0.1942 ***	-0.4815 ***	-0.3451 ***
	(0.0306)	(0.0649)	(0.0334)	(0.0473)	(0.0147)	(0.1622)	(0.0647)
Capital/labour ratio	0.1736***	0.0242	0.0444**	0.0770***	0.0768***	-0.0751	0.0612 ***
	(0.0253)	(0.0193)	(0.0193)	(0.0221)	(0.0159)	(0.0595)	(0.0142)
Firmage	0.0148*	0.0195*	0.0153	0.0447***	0.0602***	0.0235	0.0483 ***
	(0.0087)	(0.0106)	(0.0107)	(0.0074)	(0.0065)	(0.0321)	(0.0081)
D_FDI	-0.1367	0.1428	0.1186	0.1314*	0.2298**		-0.0629
	(0.1312)	(0.1017)	(0.0726)	(0.0784)	(0.0933)		(0.0547)
Firmsize	-0.2154***	-0.0716 ***	-0.1135***	-0.1329 ***	-0.0948 ***	-0.1213*	-0.1286 ***
	(0.0379)	(0.0257)	(0.0370)	(0.0446)	(0.0279)	(0.0676)	(0.0271)
HHI	-2.0219	-120.7330 ***	-174.3021 ***	-11.8689 **	-17.2009	-43.2452	-5.4119
	(4.9616)	(40.3858)	(47.2712)	(5.3215)	(11.2410)	(26.2959)	(13.5194)
Firms in imports and export	0.0849**	0.0466	-0.0169	0.0275	0.0704**	0.0456	-0.0129
	(0.0362)	(0.0295)	(0.0298)	(0.0349)	(0.0296)	(0.0817)	(0.0304)
Inflation	-0.9037***	-0.4090**	-0.8237***	-0.4264 ***	-0.7257 ***	-0.9896**	-0.4244 ***
	(0.1213)	(0.1688)	(0.1333)	(0.1520)	(0.1021)	(0.3913)	(0.1492)
Constant	2.1809***	2.6721***	3.0669***	2.2761***	1.8891***	3.6372 ***	2.1383 ***
	(0.1996)	(0.2156)	(0.2913)	(0.2165)	(0.1384)	(0.5210)	(0.1762)

Observations		5,442	6,841	5,078	5,365	9,533	872	6,992
Number of ID		2,316	2,924	2,254	2,245	4,308	438	2,966
Arellano-Bond test0	AR1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	AR2	0.0943	0.1083	0.4170	0.5849	0.2789	0.2963	0.0741

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Export activity significantly enhances TFP only in Groups 1 and 5 – particularly, food processing and non-metallic minerals – thus revealing sectoral heterogeneity in productivity drivers. Labour-intensive, export-oriented sectors (Groups 1 and 2) are more sensitive to energy costs, which offers clear efficiency gains; whereas resource-based industries (Groups 3 and 5) face structural constraints from simple processes and domestic supply chains. Capital-intensive, regulated sectors such as chemicals (Group 4) benefit from policy support, while electronics (Group 6), dominated by FDI, reflect standardized large-scale production. Group 7 relies on imported technology, with productivity driven by equipment upgrades rather than operational energy efficiency. To address potential confounding from value added fluctuations and input-mix differences, we controlled for capital intensity, estimated sector- and region-specific models, and tested coefficient stability. Results confirm that the negative EI–TFP relationship reflects genuine efficiency differences, rather than mechanical artefacts.

5. Conclusions

The results show that Vietnamese firms with lower energy intensity and greater capital deepening achieve higher TFP, with stronger effects observed among firms that are more deeply integrated into international markets through trade and foreign direct investment. These findings highlight energy efficiency as a key driver of firm-level productivity, rather than solely a cost-reduction strategy.

Policy implications point to the need for differentiated approaches. Small and medium-sized enterprises would benefit from subsidized energy audits, financial incentives for equipment upgrading, and training programmes to strengthen energy management capabilities. For large firms and FDI-oriented enterprises, mandatory efficiency standards and public disclosure requirements should be enforced, with fiscal or land-use incentives linked to measurable energy performance improvements. At the subnational level, provincial authorities should tailor energy efficiency programmes to regional industrial strengths and promote partnerships with energy service companies through shared-savings models. At the macro level, maintaining macroeconomic stability and policy coherence remains essential for sustaining productivity growth.

However, his study is limited by the use of energy intensity as a proxy for energy efficiency, and by the absence of detailed energy price and technology data. Future research should therefore incorporate richer efficiency indicators and quasi-experimental designs to strengthen causal inference.

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Appendix

Vietnam's six socio-economic regions (with corresponding provincial codes)

- **Region 1 – Northern Midlands and Mountain Areas (14 provinces):** Ha Giang (02), Cao Bang (04), Bac Kạn (06), Tuyen Quang (08), Lao Cai (10), Dien Bien (11), Lai Chau (12), Son La (14), Yen Bai (15), Hoa Binh (17), Thái Nguyên (19), Lang Sơn (20), Bac Giang (24), Phu Tho (25).
- **Region 2 – Red River Delta (11 provinces):** Hanoi (01), Quang Ninh (22), Vinh Phuc (26), Bac Ninh (27), Hai Duong (30), Hai Phong (31), Hung Yen (33), Thai Binh (34), Ha Nam (35), Nam Dinh (36), Ninh Binh (37).
- **Region 3 – North Central and Central Coastal Areas (14 provinces):** Thanh Hoa (38), Nghe An (40), Ha Tinh (42), Quang Binh (44), Quang Tri (45), Thua Thien Hue (46), Da Nang (48), Quang Nam (49), Quang Ngai (51), Binh Dinh (52), Phu Yen (54), Khanh Hoa (56), Ninh Thuan (58), Binh Thuan (60).
- **Region 4 – Central Highlands (5 provinces):** Kon Tum (62), Gia Lai (64), Dak Lak (66), Dak Nong (67), Lam Dong (68).
- **Region 5 – Southeast (6 provinces/cities):** Binh Phuoc (70), Tay Ninh (72), Binh Dương (74), Dong Nai (75), Ba Ria – Vung Tau (77), Ho Chi Minh City (79).
- **Region 6 – Mekong River Delta (13 provinces/cities):** Long An (80), Tien Giang (82), Ben Tre (83), Tra Vinh (84), Vinh Long (86), Dong Thap (87), An Giang (89), Kien Giang (91), Can Tho (92), Hau Giang (93), Soc Trang (94), Bac Lieu (95), Ca Mau (96).

Table 4. Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min	Max
Loga TFP	196866	2.7244	0.7595	-3.2393	7.3077
EI	196866	0.3719	0.8396	0.0100	9.9981
Loga R	196866	3.9709	1.6520	-8.1570	12.7660
Firmage	196866	9.6515	7.4652	1.0000	99.0000
D_FDI	195097	0.3783	0.2160	0.0011	1.0000
Firmsize	196866	1.8946	0.7519	1.0000	4.0000
HHI	196866	0.0032	0.0054	0.0008	0.2456
XK	196866	0.3190	0.4661	0.0000	1.0000
CPI	196866	0.3445	0.1674	-0.3964	1.2396

Table 5. Results combined industry groups in the processing and manufacturing industry

Code (VSIC 2018)	Type of Manufacturing Industry	Industry groups
10	Manufacture of food products	
11	Manufacture of beverages	Group 1
12	Manufacture of tobacco products	
13	Manufacture of textiles	
14	Manufacture of apparel	Group 2
15	Manufacture of leather and related products	
16	Manufacture of wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	
17	Manufacture of paper and paper products	Group 3
18	Printing and reproduction of recorded media	
19	Manufacture of coke and refined petroleum products	
20	Manufacture of chemicals and chemical products	
21	Manufacture of pharmaceuticals, medicinal chemicals, and botanical products	Group 4
22	Manufacture of rubber and plastic products	
23	Manufacture of other non-metallic mineral products	
24	Manufacture of basic metals	Group 5
25	Manufacture of fabricated metal products (except machinery and equipment)	
26	Manufacture of electronic, computer, and optical products	Group 6
27	Manufacture of electrical equipment	
28	Manufacture of machinery and equipment N.E.C.	
29	Manufacture of motor vehicles; trailers and semi-trailers	
30	Manufacture of other transport equipment	
31	Manufacture of furniture	Group 7
32	Other manufacturing	
33	Repair and installation of machinery and equipment	
35	Electricity, gas, steam, and air conditioning supply	